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Perspective

Vagrants as vanguards of range shifts in a dynamic world

Robert A. Davis[a,b,*], David M. Watson[c]

[a] School of Science, Edith Cowan University, 100 Joondalup Drive, Joondalup, WA 6027, Australia
[b] School of Biological Sciences, University of Western Australia, 35 Stirling Highway, Crawley, WA 6009, Australia
[c] Institute for Land, Water and Society, PO Box 789, Charles Sturt University, Albury 2640, Australia

ABSTRACT

The recent capture and removal to captivity of the first Nicobar Pigeon in Australia on the basis of biosecurity concerns, provides a compelling opportunity to examine how we manage species that naturally disperse to new territories. With the spectre of increasing climate change there is an increasing recognition of the need for species to expand or shift their ranges as part of natural adaptation. The occurrence of vagrants is a natural phenomenon that may be increasing as a result of climate change and other disturbances, but self-introduced organisms are known world-wide in multiple taxa. Although most vagrants are short-lived and of little lasting ecological consequence, some represent the forerunners of climate adaptation—individuals best placed to found new populations beyond their previous range. In contrast to invasive species for which policies and legislative instruments are commonplace (including watch lists of the world's worst invaders), policy makers have failed to consider the inherent dynamism of distributional ranges and the important role of vagrants as first responders to environmental change. The application of ad-hoc policies considering individual vagrants as a biosecurity risk is ill-informed, ecologically indefensible, and potentially counter-productive. We articulate the need for a new framework to consider vagrants as climate refugees and challenge conservation managers and on-ground practitioners to take active roles in determining how they are both viewed and managed.

1. Introduction

An illegal immigrant was found in Australia's remote northwest in April 2017 and, after a brief pursuit, the individual was apprehended and taken into custody by the appropriate authorities. Although the incident occurred in a remote Indigenous settlement, details of this case captured the public's attention via a series of media stories (ABC News, 2017). Rather than a person seeking asylum, the refugee in this case was a bird: a wild Nicobar Pigeon *Caloenas nicobarica*, a near threatened species that had most likely flown to the Kimberley across the Indian Ocean from Indonesia. Though many birds hitch rides on ships, this is a remote part of the West Australian coastline with the nearest port over 1000 km away. The Nicobar Pigeon is also a strong flier with a broad distribution throughout oceanic islands of the Asia-Pacific region and the only previous record for Australia in 1989 was considered a self-introduced individual (Birdlife Australia Rarities Committee, 2017). The captured bird was given a thorough health check and cleared of any pathogens, parasites and potential weed seeds before being transferred to Adelaide Zoo, where a breeding group of Nicobar Pigeons is kept and displayed.

Vagrants are nothing new, but the response of Australian Quarantine and Inspection Services was unprecedented, taking the bird away to a secure facility never to be released into the wild again. This extraordinary government action raises several ecological and ethical issues that the scientific and wider community need to consider:

- Do vagrant animals represent a genuine biosecurity risk, given that species have been coming and going for millennia?
- If we remove these individuals, are we interfering with the natural potential for species range shifts and adaptation, especially in the face of accelerating climate change?
- Do we need a policy on vagrants? Are such unilateral actions a case of “playing God” without the ecological knowledge?

2. Legislative context

Globally, vagrant species are typically ignored, rarely acknowledged, let alone defined in policies or legislation. While migratory species are well protected under international acts such as the Migratory Bird Treaty Act 1918 (USA), international bilateral and multilateral agreements, such as the China-Australia Migratory Bird Agreement and the Agreement on the Conservation of African-Eurasian

* Corresponding author at: School of Science, Edith Cowan University, 100 Joondalup Drive, Joondalup, WA 6027, Australia.
E-mail address: robert.davis@ecu.edu.au (R.A. Davis).

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Migratory Waterbirds, respectively, vagrant species are poorly addressed if at all. There are some exceptions such as in New Zealand, where all vagrant and colonising birds have received default protection since the Wildlife Act 1953 came into effect. Similarly, the UK maintains a list of species occurring 'naturally' (including vagrants) that are all protected under the Countryside & Wildlife Act. The exact legal status of vagrants is difficult to find for many jurisdictions and is rarely explicitly mentioned in acts covering migratory species. Despite this obvious omission from legislation, it is increasingly recognised that records of vagrant species are increasing in frequency as species shift their ranges in response to climate change (Jiguet and Barbet-Massin, 2013). All policy documents we found relate solely to birds, but vagrants are known from a wide range of animal and plant groups, highlighting a critical gap in current legislative instruments.

3. The case for natural dispersal

Dispersal is the fodder of evolution, allowing dwindling populations to replenish and seeding the potential for lineages to diversify. Without both directed and random dispersal events, islands would not be the hotspots of endemism that they are. Long distance or "waif" dispersal occurs either as chance events or part of migratory cycles and is prevalent in plants, bats, birds, butterflies and even reptiles, amphibians and mammals via swimming or rafting. A litany of cosmopolitan species distributions are manifestations of this process—the panmictic occurrence of Eurasian Coots *Fulica atra*, Wanderer/Monarch Butterflies *Danaus plexippus* and Bracken Ferns *Pteridium aquilinum*, for example. Increasingly, however, the spread of many cosmopolitan species can also be attributed to human assistance, including the House Mouse *Mus musculus*, Black Rat *Rattus rattus* and thousands of invasive plants (Pysek et al., 2012).

The Wanderer or Monarch Butterfly is one of the best-known examples of self-introduction, now naturalised across the world. Recent research has demonstrated that this species rapidly evolved into a migratory species with a significant global dispersal event during the 1800's, but that a portion of the population remained sedentary with genes for both forms being maintained in the population (Zhan et al., 2014). Concerns are now held that the rapid decline of Monarch Butterflies may eliminate this diversity and relegate the species to low-dispersal, extinction prone populations (Zhan et al., 2014).

New Zealand, with its close proximity to Australia provides instructive case studies of self-introduction. The two land masses are home to very different numbers of species; (continental Australia has recorded 922 bird species and mainland New Zealand has 387; Gill and Donsker, 2018). Several bird species are now considered naturalised in New Zealand; established from Australian vagrants. Clout and Lowe (2000) list the Silvereye *Zosterops lateralis* (1856), Masked Lapwing *Vanellus miles* (1932), White-faced Heron *Egretta novaehollandiae* (1941), Royal Spoonbill *Platalea regia* (1949) and Welcome Swallow *Hirundo neoxena* (1958) as known self-introductions. Clout and Lowe (2000) speculate that these species have probably long been occasional vagrants to New Zealand but that human-induced land use changes made the habitat more suitable for their establishment. As well as birds, Australian plants occasionally journey to New Zealand. In 1834, a coast mistletoe *Muellerina celastroides* was found in the Bay of Islands, documented by a small sprig preserved as a herbarium specimen (Barlow, 1984). This entire genus is endemic to south-eastern Australia, and this far-flung individual is considered to have been transported as a seed by a migrating bird (Watson, 2011), the plant was resighted in the late 1830's but has not been reported since.

Extra-limital dispersal is an intrinsic aspect of the ecology and life history of many taxa, and distributional ranges are in constant flux as populations recede and grow and colonists expand into previously unoccupied areas. Subsequent establishment of new populations, regardless of geopolitical boundaries, is a natural event, offsetting local extinctions and helping ensure species persistence in the face of global and local environmental changes.

4. Climatic shifts, habitat change and dispersal

In the face of rapidly changing climates, up to 7.9% of all species are predicted to become extinct within the next century (Urban, 2015). For many of these species, the ability to disperse and increase their range away from warming, drying or otherwise increasingly unfavourable climates may buffer them against extinction if they can move fast enough (Loarie et al., 2009). It is, therefore, imperative that we allow species to disperse if we are to minimise global extinctions. These considerations increasingly include the concept of assisted migration (Hoegh-Guldberg et al., 2008) especially for those taxa that are ecologically or geographically dispersal limited (Sinervo et al., 2010; Gibbon et al., 2000) and species restricted to islands or island continents including Australia and New Zealand (Urban, 2015).

Given the spectre of rapidly changing climates, the imperative of species range shifts and the existence of migration, long-distance dispersal and occasional extra-limital vagrants as the status quo, we can expect increasing occurrence of climate refugees. By ignoring vagrants and having no legislative framework or management plans in place to recognise and respond to them, are we complicit in diminishing the adaptive capacity of species, in effect hastening their demise? To formulate an integrated response, we need to balance these ecological and evolutionary considerations with an evaluation of potential threats from species expanding their ranges.

5. Biosecurity risks

History repeatedly reminds us that colonising species (be they accidental vagrants or introduced by humans) can pose genuine threats to human, animal and environmental health and, without ongoing, strict biosecurity, disasters arise. None of these are more obvious and dramatic than the impacts of introduced (feral) cats on Australian native mammals (Doherty et al., 2015), the devastating impacts of rats on island birds (Ruffino et al., 2015) or the catastrophic loss of the avifauna of the island of Guam with the introduction of the Brown Tree snake *Boiga irregularis* (Wiles et al., 2003). Another risk from invasive species is the introduction and spread of disease as seen with the disastrous introduction of avian malaria to Hawaii implicated in the extinction of at least 10 endemic bird species (Lowe et al., 2000).

It is important to note, however, that all of the above examples relate to human-assisted species introductions. There is a genuine biosecurity risk posed by many species who have proven "rap sheets" of ecological damage and for which biosecurity surveillance should quite rightfully be conducted to detect and remove early incursions. These species could include for example, the African Giant Landsnail *Achatina fulica* (Thiengo et al., 2007), Red Imported Fire Ants *Solenopsis invicta* (Cook, 2003) and Giant Hogweed *Heracleum mantegazzianum* (Pysek et al., 2008)—all with a long history of invasion with negative consequences to ecosystems and human health.

If a species does not fit this mould i.e. it has arrived by natural means of self-dispersal and is not considered to have negative consequences on the biota of it's new home, should we be investing limited resources in tracking it down? Moreover, if the species is endangered within its native range, should the precautionary principle be applied to outlying vagrants? Although the Nicobar pigeon was captured by Indigenous rangers, it is reported to have been held "as part of biosecurity protocol" (Australian Geographic, 2017), which raises the question of why this bird was considered a risk and whether dispersing or vagrant individuals actually pose a significant biosecurity risk.

With birdwatching increasing in popularity and birders ever watchful for unfamiliar species, the best data available on vagrants relates to birds. In Australia, for example, 946 individuals of 260 species have been recorded since 1940 (Birdlife Australia Rarities Committee, 2017). Despite the large number of these occasional

visitors, which likely represent a fraction of the actual number of extra-limital individuals, the overwhelming majority of these events do not result in colonization. A review of 66 islands found that propensity to vagrancy was a poor predictor of colonization success on oceanic islands, with success more closely linked to global range size and for migrants than residents (Lees and Gilroy, 2014). Further reasons may include unmet resource needs (the desert island problem), demography (one individual does not a population make) or both, but it is impossible to know which of these events are inconsequential, and which represent the first stages of range-shift. Importantly, it is the filtering process by which thousands of waif dispersal events are needed for a single range-shift event to occur that constitutes the mechanistic basis of climate change adaptation, determining the time, the place, identity and genotype of individual founders. This might relate to the ability to withstand extended food shortage or undertake long-distance movements. It could relate to tolerance of microclimatic extremes beyond the climatic envelope defining species distributional limits. Regardless, the very factors that led to the extra-limital occurrence of these exceptional individuals are the same mechanistic factors constraining the remainder of its population.

6. Vagrants as climate refugees

To date, the only intersection between conservation science and vagrants has been within the context of invasive species management. The time for recognizing a second category of extra-limital individuals—climate refugees—is overdue. Applying lessons learned from invasive species management, we know that it is both the species AND the individual that matter. Thus, the individual found hundreds or thousands of kilometres beyond its usual distribution is, by definition, an extraordinary individual. While weather and other stochastic events may be involved, the individual able to withstand these physiological stresses is exactly the kind of individual that conservation managers would select to found a new population if they were undertaking active evolutionary management to mitigate population losses (Smith et al., 2014). Thus, the individual is disproportionately important in this discussion. Rather than an academic argument about which species should be selected for assisted migration, which traits should be used to select founders, and which regions to consider as potential refugia, these decisions have effectively already been made.

As the number of reported vagrants increases, the need for integrated policy development becomes more pressing. A total of 329 cases of vagrant birds were logged for Australia from 1940 to 2000, with an additional 617 cases in the last 17 years and 266 just in the last 7 years (Birdlife Australia Rarities Committee, 2017). Even allowing for increasing likelihood of detection, this exponential increase implies that the issue of self-introduced species will become more pressing. It is therefore an imperative that we consider what it truly means to be a native species (Gilroy et al., 2016) and consider a unified biosecurity and policy approach on this issue. Just as there are 'watch lists' of those invasive taxa considered to pose biosecurity risks, we suggest that a new list should be developed of those species most likely to become climate refugees, for which extra-limital vagrants are regarded as potential colonists of high conservation value. Indeed, we consider Nicobar Pigeons a worthy species to inaugurate such a list—as a species listed as near threatened restricted to a series of isolated islands adjacent to extensive areas of unoccupied but potential suitable habitat.

7. Prospect

To date, policy makers have failed to properly consider the needs of organisms to expand their ranges and adapt to environmental and climate change. The application of ad-hoc policies considering individual vagrants as a biosecurity risk is ecologically indefensible and ill-informed. Rather than requiring management intervention or legislative oversight, we strongly suggest governments keep a watching brief on waifs, vagrants and other climate-change refugees, understanding that knee-jerk decisions and ill-informed actions may contribute to the thousand cuts relegating species to extinction.

We suggest that countries and jurisdictions that experience a high number of vagrant species, urgently consider the protection afforded to these species and consider the possibility that they may become naturally established as part of ongoing range expansions in the face of climate change. Specifically we recommend the following to policy makers and conservation managers:

1) Create a framework to allow determination of whether a species is a natural vagrant or possibly a ship or human assisted introduction. This may include genetic testing.
2) Ensure that vagrant species with annual occurrences and increasing frequencies of visitation are protected under relevant legislation from being persecuted or disturbed.
3) Allow vagrants to remain in the natural environment to feed or breed and not be removed for biosecurity or other reasons.
4) Assess whether the vagrant species are declining or threatened in their range states and consider special protection and/or listing under existing migratory species acts.
5) Consider protection and management/enhancement of key habitats that are subject to repeat visits by vagrant species.

The easiest way to achieve the above actions may often be to amend existing migratory species legislation to include vagrants explicitly (Runge et al., 2017).

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